Impact of Tropical Cyclones on Rural Infrastructures in Bangladesh

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ABSTRACT

Tropical cyclone has a great impact on agricultures and rural infrastructures such as shelter, sanitation, drinking water, electricity supplies and transportation services. It causes huge damages not only to livelihoods but also to engineering structures like rural roads, dams, embankments, farm buildings and dairy houses etc. This paper depicts the results of recent studies on impact of tropical cyclones on rural and agricultural engineering infrastructures in Bangladesh based on the field visits to cyclone sites, collected data and information on damages and death of peoples. Necessary data related to tropical cyclones are obtained from available publications and news paper information reported in the recent years and previously. It is found that, in 2007, Bangladesh again witnessed unprecedented tropical cyclone called as "Sidr" caused enormous disruptions, damages and remarkable number of death of peoples. The country was yet to fully repair many of the damages done to her infrastructure due to devastating flood occurred in the same year just three months ago. It is revealed that the coast of the Bay of Bengal is particularly vulnerable to tropical cyclones where at least four major cyclones occurred that killed over half millions peoples especially after the Bhola cyclone. It is observed that the return period of earlier destructive cyclones was thirty to fifty years, whereas recent ones are occurring by nearly eight years, signifying the frequency of devastating cyclones. It is concluded that "Sidr" is as strong as of the previous cyclones; however, the casualties in term of number of death of people are conspicuously lower than that of the former ones, indicating the increase of awareness of people, improvement of warning system of the weather broadcasting center and the countermeasures taken by the government of the country. A discussion regarding the damages of agricultural engineering infrastructures such as rural roads, embankments, water sanitation, shelters and food security is presented.

Keywords: Bangladesh, tropical cyclones, severity, victims, rural engineering, infrastructures, counter-measures

1. INTRODUCTION

Rural and agricultural engineering infrastructures such as farm structures, irrigation structures, dairy, poultry, fisheries, shelter, sanitation, drinking water, electricity supplies and transportation services including both land and water transports are in great danger in the region of Bay of Bengal where natural disasters occur frequently. Bangladesh is a country vulnerable to cyclones associated with tidal surge particularly in pre-monsoon months of April-May and post-monsoon months of October-November. The country is also susceptible to flood associated with heavy rain and snow melts on the eroded materials from the south and southern slopes of Himalaya

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Mountains during the monsoon season (June to September). Within 37 years, the Bay of Bengal has witnessed many cyclones causing enormous disruptions, damages and remarkable number of death of peoples. The cyclones occurred in the year of 1970 (Bhola), 1991 (Tropical), 1999 (Orissa) and 2007 (Sidr) are some of the examples. The 1970 Bhola cyclone was a devastating cyclone that struck on November 12, 1970 (Islam, 2006). It was the deadliest tropical cyclone ever recorded, and one of the deadliest natural disasters in modern times. More than 250000 people lost their lives in the storm, primarily as a result of the storm surge that flooded much of the low-lying islands of the Ganges Delta. This cyclone was the sixth cyclonic storm of the 1970 North Indian Ocean cyclone season, and was also the most powerful, reaching a strength equivalent to a Category 3 hurricane. This cyclone formed over the central Bay of Bengal on November 8 and traveled north, intensifying as it did so. It reached its peak with winds of 185 km/h (115 mph) on November 12, and made landfall on the coast of East Pakistan that night. The storm surge devastated many of the offshore islands, wiping out villages and destroying crops throughout the region. The Tazumuddin area was the most severely affected, with over 45% of the population of 167000 killed by the storm (Paul and Rahman, 2006).

The cyclone which struck Bangladesh on the night of 29-30 April 1991 was particularly severe causing widespread damage, killing 138882 people (Bern, et al. 1993). There was massive damage to life line systems as well as private properties. Total loss was estimated at US$2.07 billion dollars for all sectors. Cyclone on 18th October, 1999 hit on the eastern cost of India along the Bay of Bengal affecting the coastal districts of Ganjam, Puri, Jagatsinghpur, Khurda, Gajapati and Balasore. Subsequently, the State was hit by a Super Cyclone on 29th October, 1999 with winds of more than 250 km/h, tidal waves rising 20 feet high and torrential rains. The Super Cyclone and its aftermath caused "severe" damage in the districts of Jagatsinghpur, Balsore, Cuttack, Puri, Nayagarh, Jajpur Kendrapada, Bhadrak and Khurda and "moderate" damage in the districts of Mayurbhanj, Dhenkanal and Keonjhar (BWDB, 1998). In 2007, Bangladesh suffered a natural disaster like the cyclone Sidr of November 15, an unusually powerful storm that triggered giant waves up to 30ft (7m) high and killed more than 10000 people in the south western coastal belt of Bangladesh covering the districts of Bagerhat, Barisal, Patuakhali, Pirozepur, Khulna and Satkhira. Even five days after the calamity, in village after village along the battered roads of the coastal districts, the survivors of the storm, their cheeks hollow and eyes sunken from hunger wait in vain for relief to come. True and natural disasters are a universal reality. But in modern times, it is the preparedness that counts. Damage can be minimized and rehabilitation can be effective if a nation has an organized disaster management plan. Unfortunately, Bangladesh does not. Accompanied by 260 km/h ravaging winds and sea surge as high as 30ft that swept about 20 km inland, a grade 5 hurricane, the highest level possible, devastated 23 districts in the south western part of Bangladesh at midnight on November 15, 2007 (EU, 1998). The country is yet to fully repair many of the damages done to her infrastructure due to devastating flood occurred in the same year just three months ago (Hossain and Sakai, 2008). Some destructions of devastating Sidr in term of damages of houses, flooding, fallout and uprooted of trees are shown in Fig.1. In view of the above objectives, a comparative study of the major cyclones those struck Bangladesh in the last four decades especially just before and after the independence of Bangladesh. Along with the severities, this paper also reports some countermeasures of tropical cyclones of Bangladesh taken by the government of the country. Data collected during the field visits to cyclone site, information on damages and deaths of peoples published in technical literature and news papers are analyzed and demonstrated.

Along with the damages of previous cyclones, the disruptions, damages and death of peoples occurred in the year 2007 are illustrated in various charts for better comparison. The return period of destructive cyclones, frequency, warning system of the weather broadcasting center and the countermeasures taken by the government of the country are depicted in this paper. Damages of agricultural engineering infrastructures such as rural roads, embankments, water sanitation, shelters and food security are also discussed.

Fig.1. Severities and damages of Sidr, 2007 (Daily Star)

2. SUMMARY OF MAJOR CYCLONES

Some of the major devastating cyclones that caused enormous damage and deaths of huge numbers of people and animals are summarized in Table 1. This table shows the name of the cyclones, year of occurrence, date of month of occurrence, category of severity and return period. As can be seen from this table that the all the four major cyclones are of category 3 or 5 indicating the power, severity and extent of the destructive cyclones. It is observed that the return period of the devastating cyclones was 50 years in 1970 or earlier, whereas it was 21 years in 1991. It is evident that the return period of both Orissa and Sidr cyclone is 8 years which indicates that it decreases remarkably especially in the couple of decades.

Table 1. Name of major cyclones in Bangladesh, date of their occurrence, category of severity and return period

Name of cyclones	Year of occurrence	Date and Month of Occurrence	Category of severity	Return period
Great Bhola cyclone	1970	12 November	3	50
Tropical cyclone	1991	30 April	5	21
Orissa cyclone	1999	29 October	4	8
Sidr cyclone	2007	15 November	5	8

2.1 Physical Facts, Cyclone Path and Severity

The path of the two recent severe cyclones along with the physical facts of Bangladesh is shown in Fig.2. It should be noted that Bangladesh extends between 21^o and 27^o North latitude and 88^o and 92.5^o East longitude. The Bay of Bengal is in the south side of the country. The total area is 144000 sq km and size of population is around 15 million (2007). Per capita income is around US$550.0, one of the lowest in the world. The coastal land of Bangladesh (710 km long) is of recent origin formed out of the process of sedimentation. Most parts of the area are, therefore, low lying which can be subjected to inundation even under ordinary circumstances of tides. A tidal surge accompanied by a cyclone storm makes the situation alarming which is further exacerbated by the triangular shape of the Bay of Bengal (Fig.2). The wide shallow continental shelf is conducive to amplification of surges causing wide spread flooding. The country has been subjected to frequent natural disasters in many forms, particularly cyclonic storms and tidal surges. From 1970 to 2007, four major cyclone storms and tidal surges have been reported. These indicate that Bangladesh is prone to frequent destructive tropical cyclones associated with tidal surge. The low-lying coastal areas are particularly vulnerable, thus placing these population, infrastructure, agriculture, livestock and economic development in a high-risk situation. During the 1991 cyclone, the cyclonic storm was detected as a low pressure area over the Southeast Bay and adjoining Andaman Sea on 23 April. Finally, the cyclone of hurricane intensity crossed the Chittagong coast a little north of Chittagong at 2 am of 30 April, 1991 that killed some 143000 people in Bangladesh. The aspects of the detection of the cyclone, its monitoring and prediction and weakness of warning and special weather bulletins have been reflected upon. Most of the worst affected areas are either off-shore islands or coastal areas. The less affected areas are mostly located inside and further from the coast. The 2007 cyclone Sidr smashed into the country's southern coastline late on Thursday midnight of November 15 with 250 km/h (155 m/h) winds that whipped up a five meter tidal surge and swept about 20 km inland, a grade 5 hurricanes, the highest level possible, devastated 23 districts in the south western part of Bangladesh. Gigantic walls of water smashed into the coastline, washing away everything in their path. The backwash dragged hundreds of people into the sea, bodies were towards the

shoreline -- twisted, bloated and broken -- washing up from the overflowing creeks and ponds around the villages. Death and its nauseating stench were everywhere.

Fig.2. Physical facts and path of two severe tropical cyclones in Bangladesh

2.2 Severity of Sidr (2007) Storm Surge

The big killer of cyclone in Bangladesh is the storm surge. The triangular shape of Bay of Bengal funnels high surges into the apex of the triangle where Bangladesh sits, and the shallow bottom of the Bay allows extraordinarily high storm surges to pile up. The maximum theoretical storm surge from a worst-case Category 5 cyclone is thought to be 41 feet in western Bangladesh (Islam, 2006). Sidr's maximum storm surge to the night of where the eye makes landfall is likely to be in the 20-25 foot range. The timing of landfall with respect to high tide is critically important because there is a 1.5 meter difference between low and high tide in western Bangladesh. According to mobilegeographics.com, high tide was at approximately 1.0 am local time on 15th November 2007 and Sidr made landfall about halfway between low and high tide. Thus, Bangladesh did have a little luck, as the storm tide could have been about 2-3 feet higher if Sidr hit at high tide. However, the influence of storm surge was so powerful that can be seen

from Fig.3 showing a three storied ferry comes on the ground due to storm surge of Sidr 2007. The coast in western Bangladesh has the forest (Sundarbans), the world's largest forest of mangrove trees. This region is the least populated coastal area in the country and has been part of a major reforestation effort in recent years. The portion of coast likely to receive the highest storm surge levels of 20-25 feet is virtually unpopulated. However, storm surge levels of 10-20 feet are still likely to affect areas with a population of at least a million, to the east of the Sundarbans forest, and inland from the forest.

Fig.3. Three story ferry comes on the ground due to storm surge of Sidr 2007 (Nayadigonta)

3. RESULTS AND DISCUSSION

3.1 Wind Speed and Storm Surge

In order to understand the severity of storm of the tropical cyclones in Bangladesh, a comparative study of the wind speed and storm surge of major cyclones those struck in Bay of Bengal during the last four decades is depicted in Figs.4 and **5**. The high power of the storm was mainly due to the higher wind speed which is apparent from Fig.4 for all the cases after 1970. In 1970, though the wind's speed of Bhola cyclone was not as high as of the recent cyclones (in 1991, 1998 and 2007), the number of casualties was severe at that time. The wind's speed of Bhola cyclone was nearly 227 km/h whereas the others were over 230 km/h such as 257, 237 and 247 km/h for the cyclones occurred in the year of 1991, 1999 and 2007, respectively. The storm surge, on the other hand, was recorded as 7.8, 8.8, 8.1 and 8.4 m for the cyclones occurred in those years of 1991, 1999 and 2007, respectively, as shown in Fig.5.

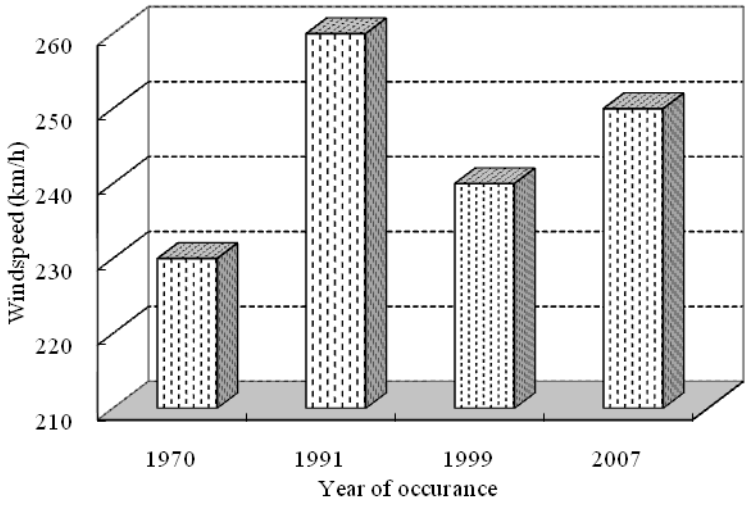

Fig.4. Wind Speed during the major cyclones in Bangladesh

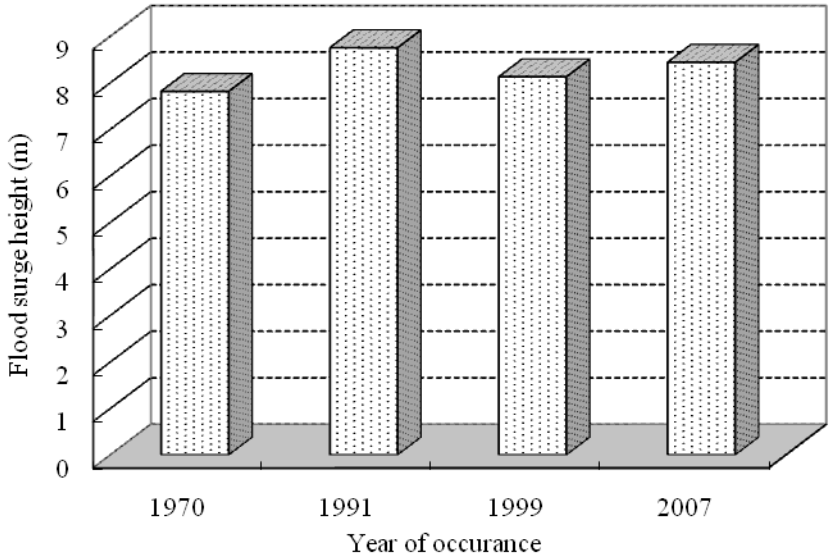

Fig.5. Flood surge height during the major cyclones in Bangladesh

3.2 Death and Damages

The number of death of people and the damages due to major cyclones in Bangladesh are given in Figs. 6 and **7** as bar diagram for the sake of clarification of the ferocious devastation brought to Bangladesh by the cyclones in 37 years. Although the wind's speed and tidal surge were lower for the 1970 Bhola cyclone than the recent ones, the number of death of people was extremely higher at that time. It was estimated that more than 250000 people was died during the 1970 Bhola cyclone. It was saying that this was the deadliest one in the earth in its history. On the other hand, the 1991 cyclone was also other deadliest tropical cyclones on record that struck

greater Chittagong with strong winds and storm surge, killing at least 140000 people and leaving as many as ten millions peoples homeless and destroying one million homes. The damage of property was estimated at 1.8 billion US dollar in 1991. The damage in 1999 and 2007 is noted as 4.2 and 5.3 billion US dollar.

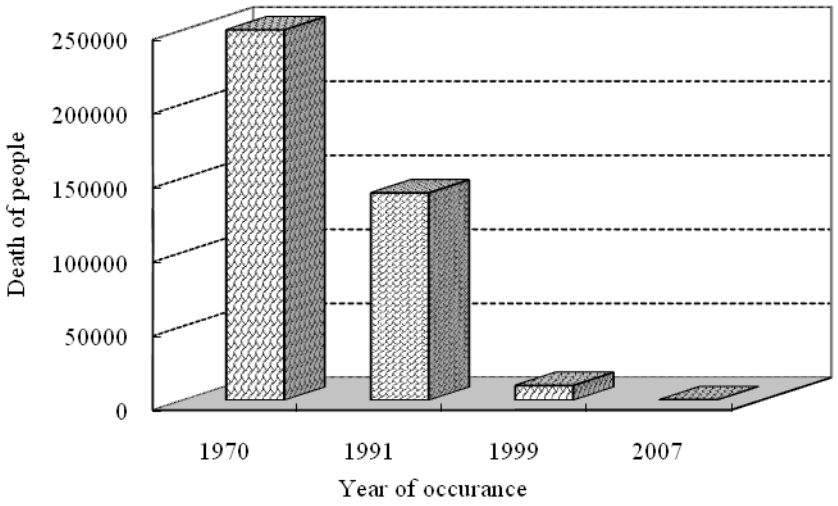

Fig.6. Number of deaths of people during the major cyclones in Bangladesh

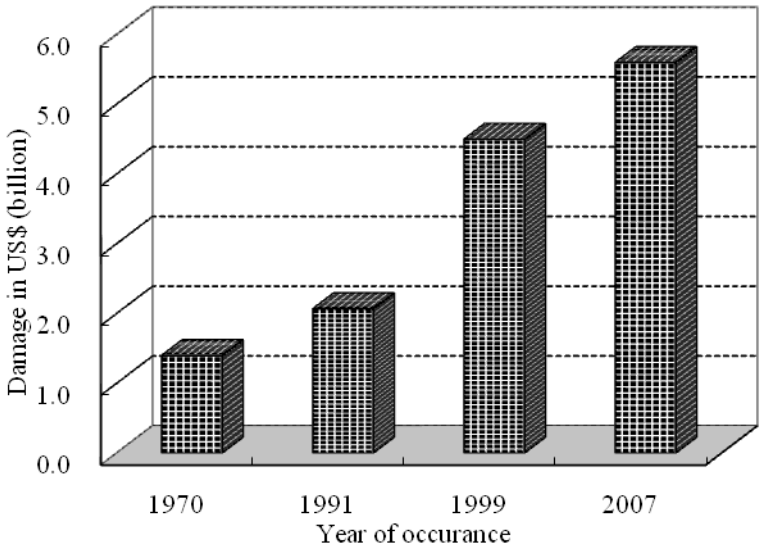

Fig.7. Damage of the properties during the major cyclones in Bangladesh

A large number of boats and smaller ships ran aground. Bangladesh Navy and Air Force were also heavily hit. BNS Isha Khan Naval Base was flooded, with heavy damage to the ships. Most of the fighter planes of the Air Force were also damaged. Comparison between the death of people (Fig.6) and the damages (Fig.7) in terms of money in US$ during the past four major

cyclones notices that the number of death of people is getting to decrease although the damages of the properties increases in the recent years. This clearly indicates the awareness and preparedness of the people in the coastal region, improvement of weather broadcasting system and countermeasures taken by the government of the country. However, these measures could not be considered enough yet and more action need to be taken to minimize the death and damages of the peoples, their homes, cattle, agriculture, forestry and fisheries, as well as its environment, bio-diversity, Sundarbans (world largest mangrove) and wildlife.

3.3 Sidr's Victims and Rehabilitation

There were a lot of Sidr victims not only in the coastal region but also in the regions neighboring the path of Sidr as it crossed on the capital of the country. An example of some of the Sidr victims from the Sharonkhola, Bagerhat is shown in Fig.8. Victims are living on a road in makeshift houses as their locality was torn up by the devastating cyclone on November 15. Rehabilitation program for Sidr-affected areas has been undertaken by the local authorities along with the government of the country and NGOs. This included economic rehabilitation, infrastructure development, disaster preparedness program and climate adaptation programs to strengthen the regional defense against future natural disasters.

Fig.8. Scores of Sidr victims in Bagerhat living on a road (Daily Star)

3.4 Countermeasures

The government has taken a number of countermeasures to prevent the lives of the peoples in the coastal regions especially after the Great Bhola Cyclone of 1970. An example of concrete cyclone shelters that was built in the cyclone prone area is shown in Fig.9. The construction of cyclone shelters was accelerated after the 1991 cyclone. This process is continued till to date and

further reinforced after the recent cyclones. Bangladesh now has over 2500 multi-purpose cyclone shelters some of it is used as primary schools also. The recent warning system in Bangladesh is fairly effective at notifying the population of an approaching cyclone. Earlier many residents were chosen not to evacuate to the shelters, since most of them are in poor condition with minimum or no maintenance at all. But now-a-days, peoples of the country are aware and showing much more response to the weather information than earlier, that saves many lives in 2007.

Fig.9. Cyclone shelter in coastal area of Bangladesh to save peoples from cyclones

Along with the government action, the NGOs also have devised cyclone preparedness programs, building shelters, organizing simulated cyclone evacuation exercises and educating villagers in the most exposed areas on how to flee. Efficient early warning systems and the widespread use of mobile phones meant that this time even people in remote regions were aware of the impending disaster. On-time information had reduced the extent of the destruction. Before the 1999 cyclone, weak technological strength and the lack of practical know-how were the main obstacles to implementing the strategy in the country.

But, recently information and communication technology, especially mobile phones and internet facilities along with the improvement of weather broadcasting technology greatly adds to an effective disaster management along with global TV channels and web sites. This involved preparing, warning, supporting and rebuilding the society before occurrence of the Sidr. However, a slight variation of landfall timing was observed. While there was a lot to cover in terms of accurately predicting, it was not clear where exactly the centre of the cyclone and when it was going to make landfall and what would be its intensity and impact. The major challenge was to convert this information into a timely evacuation plan. On mid-day of Wednesday 14th November 2007; many people were evacuated to the cyclone shelters because of the cyclone warning of Bangladesh Meteorological Department (BMD). The Storm Centre of BMD in its bulletin forecasted that cyclone Sidr would make landfall by noon. According to the Disaster Management Bureau, when the people who took shelter saw that the cyclone had still not come, they thought that it would not materialize and they left the cyclone shelters for their homes.

Many of these people felt victim to the fury of the cyclone. The BMD came under heavily criticism for having forecasted landfall ahead of time.

3.5 Rural and Agricultural Engineering Infrastructures

3.5.1 Food Security

According to UN, more than 1.6 million acres of cropland was reportedly damaged. The main crop damaged was rice that was under cultivation during this Aman season. Unlike many other regions in Bangladesh, the area affected has a single harvest during the months of November thru January. Thus the timing of the cyclone was particularly harmful, in that many of the crops were at or nearly ready for harvesting. A quarter of ready-to-harvest crops have been destroyed. Many households lost their food stocks as a result of severe damage to housing. Large numbers of cattle, buffalos, goats and poultry have been killed. The government of Bangladesh estimated that nearly 382000 livestock animals were killed; the large majority of these were believed to be cattle. The UN assessment team members witnessed many animal carcasses floating in the rivers or washed up on the river banks. Livestock losses represent not only a loss of critical household assets, with an associated loss to wealth and income, but also a loss in milk production for own consumption. In coastal areas fish were a key source of food and animal protein. During the near term period fish consumption in the diet was declined, as catches were reduced due to either damage to boats and nets etc., and/or the unavailability of labor which was diverted to other critical activities such as housing repairs and reconstruction. Fish production from household ponds and shrimp fisheries was also declined, as many ponds and shrimp cultivation areas were badly damaged and littered with storm wreckage and debris. Many small shops selling food in worst affected areas were severely damaged due to strong winds and falling trees. Food prices were already high prior to the storm due to high international food prices and earlier flood related losses, the prices became high further after cyclone. Physical access to food markets has been disrupted in some of the worst affected areas; however most of the trees blocking roads and thereby hindering the transport of food to market areas have been cleared, and so food availability in the markets was not a major concern. Where housing damages were particularly bad, household kitchens and cooking areas had been badly affected, with serious implications for the ability to cook and utilize food. Although the affected population was able to salvage some possessions, many people were unable to cook due to missing utensils.

3.5.2 Shelter

Housing damages were the most visible and tangible damages associated with cyclone. For worst affected areas UN assessment team members witnessed numerous cases of flattened, overturned or sideways leaning household structures. Piles of damaged housing and construction materials were common within the hardest hit residential areas. The total number of houses damaged was nearly 1.2 million, approximately 30% of those were reported as fully damaged, and the remaining 70% partially damaged. Approximately 697400 houses were damaged within only five districts. In many areas more than half of thatched-roof homes, primarily inhabited by the extreme poor, were completely destroyed. A high proportion of wood-framed houses with corrugated iron roofs had been destroyed or severely damaged in coastal areas. Less extensive damage was observed at locations further in land or north of the coast.

3.5.3 Water and Sanitation

Damage to sanitation facilities and infrastructure was significant. For some of the worst affected areas, one estimate puts the percentage of slab latrines damaged or destroyed as high as 70%. The affected population was vulnerable to outbreaks of diarrhea and other hygiene-related diseases. Drinking water sources in many communities had been contaminated by saline and debris. Power outages had affected water supplies in areas with piped water.

3.5.6 Transport

There was widespread damage to transport and communications networks. Rural roads, and many of the embankments protecting such roads, were extensively damaged. Most of the road damage was associated with the tidal surges in coastal areas. Large uprooted trees on roadsides also account for some of the damages, as trees were uprooted segments of tarmac or earthen roads became cracked or fragmented. Damage to transport infrastructure in coastal and inland waterways had occurred. Numerous ferries, and associated landing and loading areas damaged. In more than a few cases, the storm surge was so strong that medium to large sized ferries were actually lifted clear out of the water and beached on neighboring land.

4. CONCLUSIONS

The paper analyzes the extent and severity of tropical cyclone in Bangladesh and its countermeasures taken by the government of the country along with the NGO. There were four deadliest storms since 1970 in the Bay of Bengal and recently, the Sidr was the fiercest cyclone that had hit the region of Bangladesh in just 37 years since 1970. For a poor country like Bangladesh, a natural disaster always means a huge death toll, displacement and inconceivable destruction. The Sidr (2007) was as devastating as the earlier ones since 1970; however, it had taken far fewer lives, indicating the increase of awareness of people, improvement of warning system of the weather broadcasting center and the countermeasures taken by the government of the country. Nonetheless, the Sidr (2007) is one of the deadliest one causing thousands of people dead, millions of acres of cropland washed down by the sweeping ocean-surge, one third of Sundarban, a world natural heritage, utterly torn down, and substantial infrastructural damages have caused combined losses of assets and agricultural production. After the shattering cyclone of 1991, around 2500 cyclone shelters and 200 flood shelters were constructed in the coastal regions, but experts opine that additional 2000 shelters are badly needed. In Patenga, Chittagong, the coast has been heavily protected with concrete levees. In addition, forestation has been initiated in the coastal regions to create a green belt. About 3931 km long coastal embankment to protect coastal land from inundation by tidal waves and storm-surges, and drainage channels of total length of 4774 km have so far been constructed, but lack of maintenance has rendered them almost ineffective. A comprehensive cyclone preparedness program is jointly planned, operated and managed by the Ministry of Disaster Management and Relief (MDMR) and the Bangladesh Red Crescent Society (BRCS), and a volunteer force of more than 32000 has been trained to help in warning and evacuation in the coastal areas.

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